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**BURNER MANIFOLD APPARATUS FOR USE IN A
CHEMICAL VAPOR DEPOSITION PROCESS**

Background of the Invention

5 This invention relates to novel burner manifold apparatuses. More particularly, this invention relates to burner manifold apparatuses for micromachined burners, such as micromachined silicon burners.

10 It is known to form various articles, such as crucibles, tubing, lenses, and optical waveguides, by reacting a precursor in the flame of a burner to produce a soot and then depositing the soot on a receptor surface. This process is particularly useful for the formation of optical waveguide preforms made from doped and undoped silica soot, including planar waveguides and waveguide fibers.

15 The waveguide formation process generally involves reacting a silicon-containing precursor in a burner flame generated by a combustible gas, such as a mixture of methane and oxygen, and depositing the silica soot on an appropriately shaped receptor surface. In this process, silicon-containing materials typically are vaporized at a location remote from the burner. The vaporized raw materials are transported to the burner by a carrier gas. There, they are volatilized and hydrolyzed to produce soot particles. The soot particles then collect on the receptor surface. The receptor surface may be a flat substrate in the case of planar waveguide fabrication, a
20 rotating starting rod (bait tube) in the case of vapor axial deposition (VAD) for waveguide fiber fabrication, or a rotating mandrel in the case of outside vapor deposition (OVD) for waveguide fiber fabrication.

Numerous burner designs have been developed for use in vapor delivery precursor processes, and at least one liquid delivery precursor process has been contemplated, as disclosed in co-pending application serial no. 08/767,653 to Hawtof et al, incorporated herein by reference. Whether the precursor is delivered to the burner in vapor form or liquid form, it is important that the burner receives a distributed, even stream of precursor. This consideration is particularly important during waveguide manufacture to form accurate refractive index profiles.

In the recent past, burners for deposition of metal oxide soot have been proposed having orifices and supply channels on a small scale. The channels and orifices in these burners may have widths or diameters less than 150 microns, for example, as disclosed in commonly-owned provisional application serial no. 60/068,255 entitled "Burner and Method For Producing Metal Oxide Soot," incorporated herein by reference.

As a result, there has arisen a need for a burner manifold that may be used in conjunction with these micromachined burners and may distribute fluid uniformly and evenly to the burners. In conventional large-scale burners, this uniformity was achieved by equally large concentric rings. This solution, however, is not practical for use with micromachined burners.

Summary of the Invention

With the advent of micromachined burners, it is desirable to have a burner manifold apparatus that evenly and uniformly distributes fluid (either vapor or liquid) to the micromachined burners.

A burner manifold apparatus in accordance with the present invention comprises fluid inlets, fluid outlets, and a plurality of fluid passages. The fluid passages extend between the fluid inlets and the fluid outlets to deliver reactants to the combustion site of a chemical vapor deposition process. The fluid passages converge toward each other from the fluid inlets to the fluid outlets in that inlets of the fluid passages are spaced farther apart than outlets of the fluid passages. This arrangement facilitates delivery of reactant precursor fluid from a macro scale delivery system to a micro scale burner. The fluid passages preferably have a smaller cross-sectional area at their outlet than at their inlet.

The fluid passages generally are isolated from one another so that some fluid passages transport reactant precursor materials and other fluid passages transport combustion materials. The fluid passages at the fluid outlets are preferably shaped to match the geometry of the burner. In a preferred embodiment, the fluid outlets are slot shaped or formed as a series of in-line round holes.

The burner manifold apparatus further includes at least one pressure inducing restriction device for passing fluid therethrough in evenly distributed, narrow elongated streams. The pressure inducing restriction device is positioned between the fluid inlets and the fluid outlets. The pressure inducing restriction device preferably comprises a plate having a series of slots or linearly arrayed apertures for emitting fluid therefrom in generally linear streams of droplets.

One embodiment of the present invention includes a manifold base having a top, a bottom, a front wall, a back wall, and two side walls. The manifold base defines horizontal passages therethrough that extend between the side walls, vertical passages extending from a position within the manifold base to the top of the manifold base, and fluid inlet ports. Each fluid inlet port is located on either the front wall or the back wall of the manifold base, and each is in fluid communication with at least one of the horizontal and vertical passages. The horizontal passages preferably are parallel to the top and the bottom of the manifold base, and the vertical passages preferably are parallel to the side walls of the manifold base.

The burner manifold apparatus of the first embodiment also includes a plate mounted to the top of the manifold base. The plate defines a plurality of apertures therethrough. At least one aperture is positioned at a location above an exit of each of the vertical passages of the manifold base to allow passage of fluid from the vertical passages through the plate.

The vertical passages of the manifold base are symmetric about a first axis bisecting the top of the manifold base. The vertical passages preferably include a central vertical passage and pairs of vertical passages, each pair defined by two vertical passages spaced equidistant from the first axis. Each pair intersects a particular horizontal passage to create an array of passages within the manifold to distribute fluid symmetrically about the first axis.

The apparatus of the first embodiment further includes a manifold burner mount mounted to the top of the plate. The manifold burner mount defines fluid passages that

extend from a bottom of the manifold burner mount to a top of the manifold burner mount. These fluid passages are arranged to converge such that a distance between adjacent fluid passages is greater at the inlet of the manifold burner mount than at the outlet of the manifold burner mount.

5 The burner manifold apparatus further comprises a first gasket positioned between the manifold base and the plate. The first gasket has slots therein in alignment with grooves in the top of the manifold base. A second gasket preferably is positioned between the plate and the manifold burner mount. This second gasket has slots in alignment with the slots in the first gasket. A burner gasket may be placed upon the manifold burner mount. The burner gasket has slots in alignment with the exits of the fluid passages in the manifold burner mount.

10 Securing elements, such as clamps, may be mounted to the top of the manifold burner mount for releasably securing a burner to the manifold burner mount. The clamps each have an outer edge and an inner edge, and the inner edge has a shoulder that engages the burner. Further, the inner edge of each clamp has a tapered surface that tapers away from the top of the manifold burner mount.

15 A second embodiment of the subject burner manifold apparatus includes a plurality of manifold elements positioned in a stacked arrangement on top of a base element. The manifold elements fluidly communicate with each other via fluid passages therein. Each of the manifold elements has a different number of fluid passages, preferably increasing by two for each successive element located higher on the stack. These fluid passages converge toward each other at the outlet of the manifold apparatus. Each of the manifold elements has at least one fluid inlet port, and preferably two, with the exception of the lowermost manifold element.

20 The fluid passages preferably are linear and extend vertically through the manifold elements. The outermost fluid passages of each of the manifold elements communicate with a fluid inlet port, and inner fluid passages are isolated from the outermost fluid passages to isolate the fluids introduced into different manifold elements. The fluid passages of adjacent manifold elements are in vertical alignment. Like the fluid passages in the burner mount of the first embodiment, the fluid passages of this second embodiment are symmetric about a central fluid passage.

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Gaskets are disposed between adjacent ones of the manifold elements. The gaskets have slots therethrough to allow passage of fluid. The gaskets preferably are formed from an elastomer material.

In a third embodiment of the invention, the burner manifold comprises a tapered section having a first end and a second end, where the first end has a larger surface area than the second end. The fluid inlets are located at the first end of the manifold, and the fluid outlets are located at the second end of the manifold. The tapered section preferably has a truncated cone shape.

The burner manifold may also comprises a top section coextensive with the tapered section. The top section has a first end adjoining the second end of the tapered section, and a second end for carrying a burner.

The tapered section and the top section of this third embodiment define a plurality of fluid passages therethrough to convey fluid from the first end of the tapered section to the second end of the top section. In a preferred embodiment, the fluid passages run generally parallel to each other and converge toward each other from the fluid inlets at the first end of the tapered section to the fluid outlets at the second end of the top section. Selected ones of the fluid passages may be blocked or plugged to select, by elimination, which passages provide fluid flow.

Sub A' ~~In this third embodiment, the burner manifold is formed by an extrusion process. The burner manifold tapers from a first end to a second end or, alternatively, has a tapered section located between the first end and the second end. This can be done, for example, by plastically transforming a preform of parallel channels (honeycomb substrate) into a funnel of funneling channels. Two suitable transforming processes are hot draw down and reduction extrusion. "Hot draw down" is a viscous forming process carried out on viscously sintered preforms and is described in commonly-owned provisional application no. 60/091,107 entitled "Redrawn Capillary Imaging Reservoir", incorporated herein by reference. "Reduction extrusion" is a plastic forming process carried out on unsintered particulate preforms as illustrated in Corning's Provisional P13569 entitled "The Manufacture of Cellular Honeycomb Structures", incorporated herein by reference. Particulates of metal, plastic, ceramic and/or glass are compounded and extruded to make the preform. The top section of the manifold may be cylindrical, rectangular, or any other shape suitable for carrying a burner.~~

A fourth embodiment of the invention includes a plurality of burner mounts, a plurality of plates, and a single manifold base. The manifold has a thickness dimension between the front wall and the back wall that is greater than a thickness dimension of the burner mounts and the plates such that a plurality of burner mount/plate combinations may be mounted to the manifold.

The burner manifold apparatus of the present invention achieves a number of advantages over conventional burner manifolds. For example, the burner manifold apparatus bridges the gap between the conventional "macro" world of manifolds and the "micro" world of micromachined silicon wafer burners.

Another advantage is that the burner manifold apparatus is capable of use in conjunction with a burner having a linear flame array that evenly distributes fluid through the manifold and to either side of the burner's linear flame array.

Still another advantage is that the burner manifold apparatus may securely and precisely mount a micromachined burner wafer in place.

A further advantage is that the burner manifold apparatus may be arranged adjacent other assemblies to form an array of adjacent burners, which generate closely adjacent burner flames.

Yet a further advantage is that the burner manifold apparatus may be produced by an extrusion process or, alternatively, a hot draw down process.

Still a further advantage of the burner manifold apparatus is that the burner may be mounted to the burner mount by an anodic bond, without the need for clamps or other mechanical attachment means.

The manifold of the present invention also enables and facilitates the use of miniature micromachined burners in applications for depositing silica soot, in particular for making high purity soot for optical waveguide manufacturing processes.

Additional advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

Brief Description of the Drawings

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate a presently preferred embodiment of the invention, and, together with the general description given above and the detailed description of the preferred embodiment given below, serve to explain the principles of the invention.

Fig. 1 is an exploded perspective view of a burner manifold apparatus for use with a micromachined burner wafer in accordance with the invention;

Fig. 2 is a side elevation view, in partial cross section, of the burner manifold apparatus and a micromachined burner wafer in accordance with the invention;

Fig. 3 is a top plan view of the burner manifold apparatus, with a burner mounted thereto, in accordance with the invention;

Fig. 4 is a top plan view of a burner manifold of the burner manifold apparatus in accordance with the invention;

Fig. 5 is a side elevation view, in cross section, of the burner manifold along section line B-B in Fig. 4;

Fig. 6 is a top plan view of a pressure plate of the burner manifold apparatus in accordance with the invention;

Fig. 7 is an exploded perspective view of a second embodiment of a burner manifold apparatus in accordance with the invention;

Fig. 8 is a side elevation view, in cross section, of apparatus parts of the burner manifold apparatus shown in Fig. 7, with fluid fittings;

Fig. 9 is a top plan view of the burner manifold apparatus shown in Fig. 7;

Fig. 10 is a side elevation view of a third embodiment of a burner manifold in accordance with the invention;

Fig. 11 is a bottom plan view of the burner manifold shown in Fig. 10;

Figs. 12A and 12B are top plan views of an alternative design for the third embodiment shown in Fig. 10; and

Fig. 13 is an exploded perspective view of a fourth embodiment of a burner manifold apparatus in accordance with the invention.

Detailed Description of the Preferred Embodiments

Micromachined burners, such as those disclosed in commonly-owned provisional application serial no. 60/068,255 to Hawtof et al., have stimulated the need for a new, sophisticated burner manifold apparatus for manifolding the flow of fluid to the micromachined burners. These micromachined burners are typically constructed as wafers and are fabricated on a small scale. For example, burners used for the production of silica soot for waveguide fiber preform may be approximately 1 inch long by 1 inch wide. The length and width of the burners can be smaller or larger, limited by semiconductor wafer fabrication procedures.

These wafer burners are fabricated with precision channels or orifices having widths or diameters, respectively, typically smaller than 150 microns, and in some embodiments, smaller than 10 microns. The channels or orifices preferably are micromachined in a linear array through the burner. Such micromachining can be achieved using conventional techniques used in the fabrication of integrated circuits, such as lithography, masking, etching, photochemical processes, reactive ion etching (RIE), ultrasonic machining, vertical wall micromachining, and crystallographic etching. The specific technique used depends on the burner material, particularly the crystal structure and orientation.

Since micromachined burners are much smaller than conventional burners and are linearly symmetric about their center, conventional manifolds do not work. A need has arisen for a burner manifold suited to the new "micro" world of linearly arrayed wafer burners, representing a significant change from the conventional "macro" world of relatively large, ringed burners.

The burner manifold apparatus of the present invention includes fluid inlets, fluid outlets, and a plurality of fluid passages extending between the fluid inlets and the fluid outlets. The fluid passages converge toward each other from the fluid inlets to the fluid outlets. For example, with fluid passages of a rectangular cross section, the longitudinal axes of the fluid passage cross sections are spaced farther apart at the inlet end of the passages than at the outlet end to facilitate delivery of precursor reactants from a macro scale delivery system to the preferred micro burner. In this way, the wider spaced inlets facilitate easy piping, whereas the closely spaced outlets enable alignment with the orifices of a miniature burner. Likewise, the fluid passages

preferably have a smaller cross-sectional area at the fluid outlets than at the fluid inlets. Thus, the burner manifold apparatus is particularly suited for use with a micromachined burner.

Referring now to the drawings, wherein like numerals indicate like parts, and initially to Fig. 1, there will be seen a first embodiment of a burner manifold apparatus, generally indicated 10, in accordance with the invention. The burner manifold apparatus 10 generally includes a manifold base 12, a pressure plate 14, and a manifold burner mount 16. The manifold base 12 illustrated in Fig. 1 has a top 18, a bottom 20, a front wall 22, a back wall 23 (in Fig 4), and side walls 24. Horizontal passages, such as passages 26 and 27 (see Figs. 2 and 5), extend between the side walls 24 of the manifold base 12. The manifold base 12 also has vertical passages 30a-30f (see Figs. 4-5) extending from a position within the manifold base 12 to the top 18 of the manifold base 12. With the exception of a central vertical passage 30a, each vertical passage 30b-30f intersects and extends upward from a particular horizontal passage, as will be explained below in more detail.

It will be understood that the horizontal and vertical passages may be constructed such that the horizontal and vertical passages are not perpendicular to each other. Moreover, whereas the horizontal and vertical passages illustrated are preferably linear, they may also be constructed with curvatures and undulations.

The manifold base 12 further has fluid inlet ports 32a, 32b located on either the front wall (32a) or the back wall (32b). The fluid inlet ports serve as ports for fluid lines to introduce vapors and/or liquids into the manifold. Each fluid inlet port fluidly communicates with at least one of the horizontal and vertical passages. The horizontal passages, the vertical passages, and the fluid inlet ports intersect with each other to facilitate symmetric distribution of fluid within the manifold.

Turning to Figs. 2, 4, and 5, the vertical passages 30a-30f are symmetric about a first axis A-A bisecting the top 18 of the manifold base 12. The vertical passages include a central passage 30a and pairs of vertical passages 30b-30f. Each pair 30b-30f is defined by two vertical passages that are spaced equidistant from the first axis A-A to distribute fluid symmetrically about the first axis A-A. Each pair 30b-30f intersects a particular horizontal passage to create an array of fluid passages within the manifold base 12. In another embodiment, the pairs 30b-30f may be symmetric about a central passage 30a that lies off of the first axis A-A.

The vertical passages 30b-30f are located at different cross-sectional planes within the manifold, where the planes are defined parallel to section line B-B and extend through the manifold top-to-bottom. Vertical passages 30a and 30b fall on the same plane, as shown in Fig. 4. The vertical passage 30a and pair 30b are located on section line B-B; pairs 30c and 30d are offset from section line B-B, closer to the front wall 22 of the manifold base 12; and pairs 30e and 30f are offset from section line B-B, closer to the rear wall 23 of the manifold base 12. The vertical passages 30b-30f (and their associated horizontal passages) are fluidly independent from each other so that, for example, a first fluid can be piped through vertical passages 30b and a second fluid can be piped through vertical passages 30c. One of skill in the art will recognize that the exact placement of the vertical passages at various planes within the manifold base 12 can be altered, as long as their symmetry about the first axis A-A is maintained.

As to the horizontal passages, such as passages 26 and 27, they are located at different heights in the manifold base 12 and span the manifold base 12 between the side walls 24. The height location of the horizontal passages is marked by the location of the fluid inlet ports 32a, 32b shown in Fig. 2. For example, Fig. 2 shows a horizontal passage 26 located at a height marked by lowermost inlet port 32b and a horizontal passage 27 located at a height marked by another higher inlet port 32b. Each horizontal passage is fed by a single fluid inlet port 32a, 32b. Put another way, each fluid inlet port 32a, 32b intersects a particular horizontal passage, with the exception of the fluid inlet port that intersects central vertical passage 30a (and that fluid inlet port is shown as the topmost of inlet ports 32a in Fig. 2). By virtue of this arrangement, a single fluid feed line splits the fluid internally in the manifold for even distribution between two vertical passages located equidistant from the central vertical passage 30a.

We have shown only two representative horizontal passages in Fig. 2, although there are five horizontal passages in a preferred embodiment of the manifold base 12, located at heights marked by the five lower inlet ports 32a, 32b. We have illustrated the horizontal passages 26 and 27 with different dashed line styles to emphasize that the horizontal passages lie in different front-to-back planes within the manifold base 12. For example, horizontal passage 26 lies at the central plane defined by section line B-B in Fig. 4. Horizontal passage 27, which, in this embodiment of the invention, fluidly communicates with the vertical passages 30f, lies in a plane closer to the back wall 23 of the manifold base 12.

In addition, the vertical passages 30b-30f are not of a uniform length. Rather, the length of the vertical passages 30b-30f varies, depending upon which horizontal passage the vertical passages 30b-30f intersect. For example, as shown in Fig. 2, the vertical passages 30f, which intersect the horizontal passage 27, will be shorter than the vertical passages 30b, which intersect the horizontal passage 26.

In slightly different terms than presented above, the orientation of the passages and ports in the manifold may be described by reference to an x-y-z coordinate system (shown beside Fig. 2). The vertical passages 30a-30f extend in the y-direction and shift along both the x-axis and the z-axis relative to each other. The horizontal passages, for example 26 and 27 in Fig. 2, extend in the x-direction and shift along both the y-axis and the z-axis relative to each other. Finally, the fluid inlet ports 32a, 32b extend along the z-axis and shift along both the x-axis and the y-axis relative to each other.

To prevent the flow of fluid out of the manifold, the horizontal passages are fitted on either end with plugs 33, as shown in Fig. 5.

The invention thus provides an intricate and effective array of fluid passageways within the manifold base that ensures an even distribution of the various fluids introduced through the inlet ports to both sides of the first axis A-A.

The top 18 of the manifold base 12 includes grooves 34 positioned above the exits of the vertical passages 30a-30f. The grooves 34 are elongate and extend in a direction parallel to the side walls 24 of the manifold base 12. The grooves 34 represent the spaced apart locations of the inlets of the fluid passages in that the vertical passages 30a-30f are fluid inlets.

A pressure plate 14, a top plan view of which is shown in Fig. 6, rests atop the manifold base 12. The pressure plate 14 is separated from the manifold base 12 by a first gasket 36, as shown in Fig. 1. To allow the passage of fluid from the manifold base 12 to the pressure plate 14, the first gasket 36 includes slots 40 that are in alignment with the grooves 34 of the top 18 of the manifold base 12. The pressure plate 14 in turn includes an array of apertures 38 in alignment with the grooves 34. The apertures 38 are smaller in size than the exits of the vertical passages 30a-30f. These apertures 38 are small enough to create a high back pressure and equalize the fluid flow through the apertures on either side of the first axis A-A. For example, with vertical passages 30f, the associated fluid inlet port 32b is closer to the left passage 30f than the right passage 30f. The pressure plate 14 ensures that fluid introduced through inlet port

32b, which, unhindered, would migrate up the left passage 30f more quickly than up the right passage 30f, disperses evenly between the two passages. The pressure plate 14 in effect blocks the rapid exit of fluid from the manifold base 12 via a path of least resistance. Thus, fluid exits the manifold base 12 through the pressure plate 14 in a substantially uniform fashion through each of the apertures 38, symmetrically about the first axis A-A, and at a substantially constant pressure.

In the embodiment illustrated, the top 18 of the manifold base 12 has a cut-out, sized to accommodate the first gasket 36, the pressure plate 14, and at least a portion of a second gasket 42, as best seen in Fig. 2. The second gasket 42 separates the pressure plate 14 from the manifold burner mount 16. Like the first gasket 36, the second gasket 42 has slots 44. These slots 44 are in alignment with the slots 40 of the first gasket 36, and thus with the grooves 34 in the manifold base 12 and the aperture array 38 in the pressure plate 14.

The manifold burner mount 16 is positioned above the second gasket 42. The manifold burner mount 16 has a top 46 and a bottom 48 and includes fluid passages 50 that extend from top 46 to bottom 48. The entrances 52 to the fluid passages 50 from the second gasket 42 are in alignment with the slots 44 in the second gasket 42 and the apertures 38 in pressure plate 14. Fluid passing through the pressure plate 14 travels to the fluid passages 50 in the manifold burner mount 16. The fluid is symmetrically distributed at the time it passes through the pressure plate 14, and it remains evenly distributed as it passes through the manifold burner mount 16 to a micromachined burner mounted thereon. In the embodiment of Fig. 2, the two outermost vertical passages 30f are spare vertical passages and do not adjoin any fluid passages 50 in the burner mount; however, it will be understood that these outermost vertical passage 30f may be used with burner mounts having additional fluid passages.

As explained above, the manifold burner mount 16 is designed for use with a micromachined burner, preferably a micromachined burner having channels or orifices of a small scale. To facilitate this use, the fluid passages 50 are disposed such that the distance between adjacent fluid passages 50 is greater at the bottom 48 of the manifold burner mount 16 than at the top 46. The fluid passages 50 are preferably linear and converge, without intersecting, at the top 46 of the manifold burner mount 16, where they meet vertical passages extending through micromachined burner 58, as shown in

Fig. 2. The orientation of the passages that extend through the burner 58 is shown in Figs. 2 and 3.

Like the passages through the burner 58, the fluid passages 50 through the manifold burner mount 16 are generally rectangular, having a longitudinal axis extending between a back wall 52 and a front wall 54. The outlets 49 of the fluid passages 50 form a linear array, symmetric about a central fluid passage. This linear array produces one or more linear streams of fluid to the burner 58 mounted atop the manifold burner mount 16, and, when the fluid streams combine, the burner 58 generates a flame. The central fluid passage 50 is typically for the silica/dopant precursor materials (which can be liquid or vapor), and the remaining fluid passages 50 are for gases that react and combust with silica and dopants.

The unique structure of the manifold burner mount 16 bridges the gap between the "macro" world of manifold and the "micro" world of micromachined siliconized wafer burners. The outlets 49 of the fluid passages 50 converge such that they are spaced closer together than the inlets of the fluid passages 50 (and, hence, the vertical fluid passages 30a-30f).

The manifold burner mount 16 may be manufactured by plunge Electrical Discharge Machine (EDM) technology, either using a wire or a plunge which vaporizes the metal that comes into contact with the tip of the plunge.

The burner manifold apparatus 10 in accordance with this first embodiment further includes a burner gasket 60, which is mounted between the top 46 of the manifold burner mount 16 and the burner 58. The burner gasket 60 has slots 62 for alignment with the outlets of the fluid passages 50, including the central passage, in the manifold burner mount 16. These slots 62 are also aligned with the slots 64 that form the linear array in the burner 58. The top 46 of the manifold burner mount 16 has a cut-out for receiving the burner gasket 60 for accurate placement and alignment of the gasket 60.

The burner mount apparatus 10 in this first embodiment also includes burner securing elements 66 mounted on the top 46 of the manifold burner mount 16. The securing elements 66 secure the burner 58 and burner gasket 60 to the burner mount top 46. The securing elements 66 preferably comprise a pair of clamps releasably secured to the top 46 of the manifold burner mount 16 by screws 68 and spring rings 69. The spring rings 69 are positioned between the clamps 66 and the burner mount top 46. The

clamps 66 have screw holes 71 for receiving the screws 68. The spring rings 69 have a slightly larger diameter than the holes 71 in the clamps 66 and the coextensive holes in the burner mount top 46.

5 The clamps 66 each have an outer edge 70 and an inner edge 72. The inner edge 72 of each clamp 66 has a downwardly facing shoulder 74, as shown in Fig. 2, which engages opposite sides of the burner 58 to clamp the burner 58 in place against the burner gasket 60. Above the shoulder 74, the inner edge 72 has a tapered surface 76
tapers away from the burner 58.

10 To secure the manifold burner mount 16 to the manifold base 12, the apparatus 10 includes channels 78 that extend completely through the manifold base 12, adjacent the side walls 24, and through at least a portion of the manifold burner mount 16. The apparatus 10 further includes screws 80 for receipt by the channels 78 to attach the manifold base 12 to the manifold burner mount 16.

15 When completely assembled, the burner mount apparatus 10 has a generally rectangular configuration, with the thickness dimension from the front wall 22 to the back wall 23. As shown in Fig. 13, the manifold base 116 may be elongated in the z-direction such that several burners and burner mount assemblies may be mounted thereon, side by side. In a preferred embodiment, three fluid lines may be introduced at the front wall 118 and the back wall 120 of the burner manifold 116, totaling six fluid
20 lines. The holes 32 extend between the front wall 118 and the back wall 120, feeding the several vertical passages 30a-30f in the manifold.

This embodiment enables efficient transference of fluid to several different burner mounts, resulting in several linear arrays of flame generated by the side by side burners. The fluids introduced into the manifold base 116 are distributed evenly
25 throughout the manifold base 116, so that the burners produce essentially uniform burner flames.

Figs. 7-9 illustrate a second embodiment of the subject burner manifold apparatus. As shown in Fig. 8, this burner manifold apparatus, generally indicated 82, includes a base element 84 and a plurality of manifold elements 86a-86f positioned in a
30 stacked arrangement on top of the base 84. The base 84 is preferably solid, as shown in cross section in Fig. 8. Each of the manifold elements 86a-86f has a different number of fluid passages 88, the number of fluid passages 88 increasing for each element that is closer to the top of the stack. For example, the lowermost manifold element 86a has a

single fluid passage fed by a single fluid feed line through a port 90. The fluid passages are isolated from one another, two new outer fluid passages being introduced into the stacked arrangement with each successive manifold element from bottom to top. For example, manifold element 86b has three fluid passages, manifold element 86c has five fluid passages, and so on. In this manner, the fluid remains contained until it reaches the topmost manifold element 86f and the burner (not shown).

The manifold elements 86b-86f each have two ports 90 so that two fluid feed lines are needed for each of these elements 86b-86f. The ports 90 face opposite directions for each successive manifold element 86b-86f for ease of attachment of the fluid feed lines. Fluid is split evenly between the two ports 90 of each manifold element 86b-86f. This differs from the first embodiment, where a particular fluid is introduced into the burner mount via a single fluid inlet port and then split internally to opposite sides of the burner mount.

The manifold apparatus 82 of this second embodiment further comprises gaskets 92 positioned between adjacent manifold elements 86a-86f (the gaskets are not shown in Fig. 8). The gaskets 94 may, for example, be formed from an elastomer material, such as Viton, a product of DuPont Dow Elastomers. The gaskets include slots 94 that align with the fluid passages in the manifold elements 86a-86f. All of the gaskets 92 may be formed with the same number of slots 94, as illustrated by the two gaskets shown in Fig. 7; only those slots in alignment with fluid passages being used (for example, only the central slot being used for the gasket positioned between elements 86a and 86b). The slots 94, like the fluid passages 88, are rectangular in shape.

Fig. 9 shows a top view of the topmost manifold element 86f in the stacked arrangement. Here it is apparent that the fluid passages 88 are rectangular in shape, with a longitudinal axis extending between a front wall 96 of the manifold element 86f and a back wall 98. The fluid passages form a linear array such that a burner, for example, burner 58 in Fig. 1, placed on top of the topmost manifold element 86f would produce a linear flame. And, as with the first embodiment, the fluid passages are symmetric about a central fluid passage and converge at the fluid outlets of the fluid passages. In addition, the cross section of the fluid inlets are greater than the cross section of the associated fluid outlets.

The manifold elements 86a-86f may be releasably connected by four long rods (not shown), each channeled in a vertical direction through a set of bores 100 formed in each corner of the manifold elements 86a-86f, the base element 84, and the gaskets 92. The rods may be threaded on each end for receipt of a nut to secure the rod in place on the topmost manifold element 86f and the base element 84. Also shown in the top view of Fig. 9 are bores 101 for receipt of alignment pins (not shown).

Like the first embodiment, this second embodiment may be used with a micromachined burner to produce a linear flame for use during a flame hydrolysis process.

Figs. 10-12 show a third embodiment of the subject invention. A burner manifold, generally indicated 102, provides a web-like or honeycomb structure capable of use with micromachined silicon wafer burners. The burner manifold 102 includes a tapered section 104 and a top section 106. The top section has a first end 107 and a second end 108. A burner may be mounted to the second end 108 of the top section 106.

The tapered section 104 has a first end 110 and a second end 112. The first end 110 has a larger diameter than the second end 112. The top section 106 is coextensive with the tapered section 104; the first end 107 of the top section 106 adjoins the second end 112 of the tapered section 104.

The tapered section 104 and the top section 106 define a plurality of fluid passages 114 therethrough. The fluid passages 114 convey fluid from the first end 110 of the tapered section 104 to the second end 108 of the top section 106. The fluid passages 114 converge, yet remain isolated from each other, in the tapered section 104 and this fluid passage convergence is carried over into the top section 106, as shown in Fig. 10.

As shown in Fig. 11, the fluid passages may have rectangular cross sections, forming slots, similar to the shape of the passages in the first two embodiments. Here, the top section 106 has a rectangular cross section; however, it will be understood that the top section 106 can have any configuration suitable for use with a micromachined burner. For example, the top section may be cylindrical, as shown in Fig. 12A and indicated 115. This cylindrical top section 115 has fluid passages 116.

In one aspect of the invention, selected ones of the fluid passages may be filled or plugged with a fill material to block the passage of fluid therethrough. Blocking of

selected fluid passages makes it possible to form fluid passages of any cross-sectional shape. For example, selected fluid passages may be blocked to form rectangular slots similar to those shown in Fig. 11, each rectangular slot being comprised of several unblocked fluid passages surrounded by blocked fluid passages, as illustrated in Fig. 12B. The unblocked passages 116, in combination, have a rectangular cross-section.

This third embodiment may also be formed with only the tapered section. The tapered section has a first end for carrying a micromachined burner and a second end, the first end having a smaller surface area than the second end. The tapered section defines a plurality of fluid passages therethrough to convey fluid from the first end to the second end, and selected ones of the fluid passages may be blocked to prevent fluid from passing therethrough.

The burner manifold 102 may be manufactured by reduction extrusion and/or hot draw down processes and preferably comprises a glass material, such as PYREX, so that a silicon burner can be bonded directly to the second end 108 via an anodic bond, alleviating the need for clamps to secure the burner to the manifold. Alternatively, the burner manifold 102 may be composed of a silica material or a ceramic material. The silica and ceramic manifolds can be formed by cold reduction extrusion.

Typically, to manufacture the manifold of Figs. 10-12, a preform of parallel channels (honeycomb) is extruded from particulate material compounded with liquid additives. In the special case of amorphous particles that viscously sinter, the viscously sintered preform can be hot drawn down viscously to make a taper of channels, a funnel of funnels. In the general case, the particulate preform (wet-green and plastic) can be reduction extruded into a taper. The channels of the particulate preform can then be backfilled with a material, such as a polycrystalline wax, which matches the plasticity and incompressibility of the webs of the particulate preform sufficiently so as to then allow the assembled structure (plastic composite) to plastically deform in a reasonably self-similar manner as it is extruded into a die of the desired manifold shape. Suitable particulate materials include glass, ceramic, metal and/or plastics. After reduction extrusion of the backfilled honeycomb preform, the backfill is removed from the channels, and the particulate taper is sintered. With a large array of channels, selected channels can be permanently filled or plugged to conveniently create a desired flow pattern through the taper. In this manner, the ensemble of fluid passages can take on any pixelated shape, depending on which passages are blocked and which are not. The

backfill material may be removable (by a variety of methods) so as to leave an array of fluid passages, or it may be permanent so as to form an array of filaments, or some combination of the two.

5 Manufacture of this third embodiment by extrusion is a particularly convenient method for impressing a taper on a honeycomb structure, and can be carried out by forcing the honeycomb from a suitable supporting enclosure (i.e., the barrel of a ram extruder) partially into or through a tapered barrel, mold or extrusion die of a desired prismatic, conical, or other tapering form. The extrusion path preferably has an inlet cross section close in size and shape to that of the supporting enclosure for the starting
10 honeycomb. The extrusion path preferably offers a smooth transition to an outlet or receptacle having a different cross-sectional size and/or shape, corresponding to a predetermined channel size and shape for the final honeycomb product.

Any size reduction carried out between the die inlet and outlet will dictate a corresponding increase in cell density and overall reduction in cell wall thickness in the
15 reshaped product, while any change in outlet shape will modify the final cell shapes and/or cell wall thickness distributions in that product. Both are accomplished without any loss of channel integrity, because flow paths do not cross.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific
20 details, and representative devices, shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims.